

Thesis/
Reports
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**Does the Presence of Introduced Trout Affect the Presence and Abundance of Columbia
Spotted Frogs (*Rana luteiventris*) in a High-Elevation Drainage Basin, Montana?**

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Abstract

One objective of this study is to assess presence, abundance, and distribution of larval, juvenile, and adult spotted frogs as related to trout presence and population structure of nearly forty high-elevation (>2700 m) water bodies. Previous work in high-elevation waters has determined a negative effect of introduced fish presence on native amphibians. Lakes and ponds of the study area have been recently stocked with Brook trout (*Salvelinus fontinalis*) and Arctic grayling (*Thymallus arcticus*). Native Columbia spotted frogs (*Rana luteiventris*) are the sole amphibian representative in the study area and are expected to be affected by fish introductions. Field surveys suggest that fish and frogs coexist in several sites, contrary to results expected from similar studies (Bradford et al. 1993, Pilliod and Peterson in press). Physical data from each site was also collected to identify variables that may influence the presence/absence of Columbia spotted frogs and breeding activity. The effect of these physical factors may be mediated by suspected biological interactions with introduced fish. The information collected in the first survey year offer several possible options for future research. Future work should focus on those abiotic and biotic factors which allow coexistence and determine any effect of trout presence on the ecology of spotted frogs.

Introduction

High-elevation, fishless waters in western North America probably once constituted major population centers for species of amphibians whose aquatic larvae are vulnerable to fish predation. Studies across many western mountain ranges have established that fish introductions can alter distribution patterns of native frogs and salamanders, even apparently contributing to their recent extirpation at local and possibly regional scales (Bradford 1989, Bradford et al. 1993). In waterbodies where trout and frogs cooccur, breeding success and subsequent recruitment is probably reduced. It is reasonable to assume that trout presence will also confine the distribution of frogs to microhabitats within a lake and between lakes in the watershed. The Beartooth Plateau, Montana is one of the few locations where a large proportion of high mountain lakes are fishless (>10%). Initial survey work will yield a baseline inventory of Columbia spotted frog (*Rana luteiventris*) distribution of all life-history stages in almost forty water bodies of the region. This pilot project will also attempt to determine any effect of fish presence on frog presence and abundance.

The Beartooth Plateau in south-central Montana and northern Wyoming has a trout fishery largely sustained by continued fish stocking with most lakes on eight-year stocking schedules (Marcuson 1985, Marcuson and Poore 1991). However, some lakes have never been stocked or no longer support fish. The Beartooth mountains are one of the few areas in the western United States where more than 10% of the large, high-elevation lakes are maintained in fishless condition (Bahls 1992). Amphibian species likely to be represented in lakes of the

Beartooth Plateau (Maxell in review, Reichel and Flath 1995) include the Tiger salamander (*Ambystoma tigrinum*), Boreal toad (*Bufo boreas boreas*), Columbia spotted frog (*Rana luteiventris*), and Boreal chorus frog (*Pseudacris triseriata*). Field surveys of the Absaroka-Beartooth Wilderness Area conducted during the summer of 1999 found only the Columbia spotted frog (*Rana luteiventris*). The absence of the other species is not fully understood. The surveyed population of spotted frogs is at the easternmost edge of the species current range. Oregon spotted frog (*Rana pretiosa*) populations in Washington and Oregon and Nevada and Utah populations of Columbia spotted frogs (*Rana luteiventris*) are highly fragmented and are candidates for federal listing (Stebbins 1985, Green et al. 1997, Corn personal communication).

A fisheries management plan was developed for the Absaroka-Beartooth Wilderness Area in 1980 (Marcuson 1985, Marcuson and Poore 1991). The Montana Department of Fish, Wildlife and Parks (MTFWP, Billings) maintains a computer data base on the lakes with fisheries, with information on stocking schedules, fish species composition and fish population densities. Selected lakes are surveyed annually by MTFWP crews to detect fish abundance and general health of the fish (Stiff, personal communication). Although detailed information on fish populations exists (e.g., general health), there is a paucity of data regarding amphibians. While presence of amphibian species has recently been included in reports by MTFWP and USFS crews, we have no information on species abundance and distribution in this area. Also, amphibian identification by these anecdotal reports can be inaccurate.

Methods

The 1999 field season focused in an area of the Absaroka-Beartooth Wilderness Area where incidental 1998 summer sightings of Columbia spotted frogs (*Rana luteiventris*) were reported (Butler & Stiff, personal communication). These lakes (Little Washtub, Sliver, and Moccasin) along with 35 other water bodies that drain into the Clarks Fork of the Yellowstone River in Montana were surveyed (Figure 1). This survey included every water body within a 5 mi² area. Lakes/ponds represent those that have never been stocked with fish (n=23), lakes historically stocked but currently lacking fish (n=1), and lakes where fish have been maintained by frequent stocking or are self-sustaining (n=13). None of these sites have natural populations of fish and stocked lakes support only one species of fish. Twelve sites support a Brook trout (*Salvelinus fontinalis*) population and only one contains Arctic grayling (*Thymallus arcticus*).

Basic limnological data for each water body include: water temperature, pH, dissolved oxygen concentration, carbon dioxide concentration, water clarity, and maximum depth. Measurements were taken randomly from the periphery. Water temperature was measured using a standard alcohol thermometer and measurements were taken a meter from shoreline at 2 cm below the surface. At some sites, water temperature was taken near egg masses. pH was measured using standard litmus paper and was rounded to the nearest whole number. pH measurements were taken a meter from shoreline at 2 cm below the surface. Dissolved oxygen and carbon dioxide concentration samples were taken only from the major lakes and analyses (ppm) were conducted the same day using LaMotte water chemistry test kit. Accuracy of these measurements is suspect and will not be used in further analysis. Water was visually inspected for clarity and a rough estimate of Secchi depth was made. Maximum depth was determined

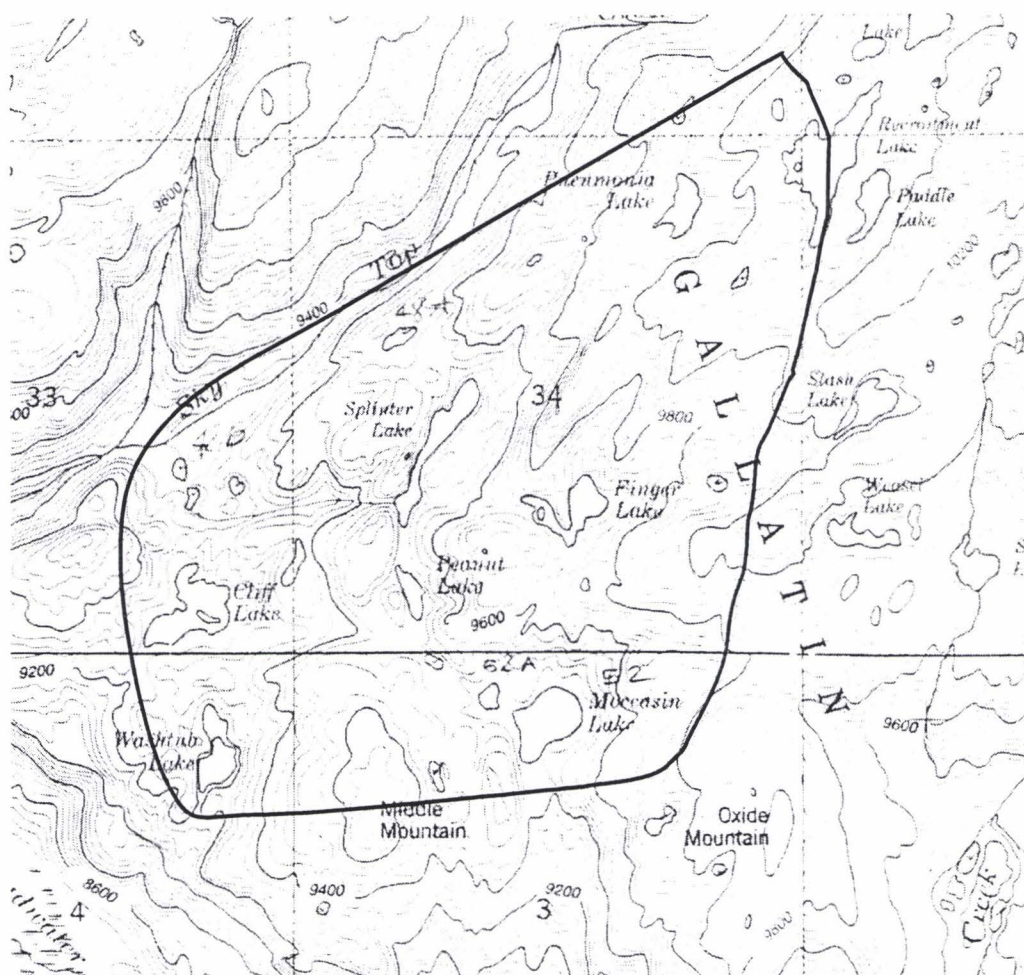


Figure 1. Fossil Lake, MT. 7.5" USGS topographical map. Study area circled.

from data collected and maps drawn by Pat Marcuson, visual inspection and direct measurement using a metric tape measure. Water was clear enough to allow estimates of maximum depth in areas where taking a direct measurement was impossible. Limnological data collection was limited during the initial field season.

Water bodies vary in wetted surface area, elevation, depth, spatial pattern, and hydrologic connectivity with other waters, habitat composition, fish presence, and feasibility of access. Although a variety of water bodies were surveyed, no a priori stratified sampling schemes were planned. All water bodies encountered within the study site were included. An attempt was made to include several fish and fishless lakes/ponds that match environmental conditions (elevation, area, depth) to the degree feasible. Shoreline and littoral habitat of each lake was described (Crisafulli 1997) and mapped roughly to scale.

Fish sampling was only conducted in lakes not recently surveyed (> five years) by MTFWP crews. Some lakes that were included in this survey may have been sampled more recently, but data was not available at the time. Fish presence was verified or added sometimes where records proved inaccurate or missing. In smaller lakes and temporary ponds trout presence and relative abundance was assessed using surface visual observation. Fish were sampled using hook and line and gill net sets. MTFWP provided a gill net typically used by

crews in fish sampling. Two days were spent with Rich Stiff (MTFWP, Billings) to learn set-netting methods and subsequent processing of netted fish. The gill net used is 30 m long, 1.2 m deep, with three mesh sizes distributed equally. Gill nets were set from shore usually across an inlet or outlet. Set sites had to be accessible along the shoreline so that the investigator could walk the margin to the other side, limiting the possible placements. The primary target of this effort was to survey fish presence, size distribution, and to provide specimens for stomach analysis. Fish stomach contents were analyzed for presence of amphibians.

Amphibian sampling was conducted exclusively using the daytime visual encounter survey (VES) (Thoms et al. 1997). Other sampling methods were not included in consideration of limited time, limited equipment and rugged terrain. Lake water is exceptionally clear making the VES the most useful and efficient. The shoreline and littoral zone were searched for amphibian presence (adult, juvenile, larvae, egg masses). Maximum survey effort occurred during late morning and early afternoon, during the mildest daily conditions. Searches were conducted from shore to allow for maximum water visibility. The entire accessible shoreline of most water bodies was surveyed and survey time was dependent on shoreline perimeter. Only two lakes were not completely surveyed (Recruitment and Hunger Lakes) because of extensive lake perimeter or unlikely amphibian presence due to unsuitable habitat and elevation (> 2910 m). A subset of lakes/ponds close to base camp was surveyed several times to learn if survey results were consistent. It was found that the visual survey technique was accurate in revealing relative abundances of frogs. The location of the greatest density of adults, juveniles, larvae, and egg masses was marked on the lake/pond maps. Every adult and juvenile encountered was counted and an attempt was made to capture each by hand or using a long-handled dip net. The SVL of each captured individual was measured. The sex of adults was determined using several features (thumb pads, vocalization, and size). No attempt was made to quantify larval abundance though rough estimates were recorded. Dozens of tadpoles were captured and STL measured. Gosner (1960) stage was not identified. The number of egg masses was estimated (average cluster diameter ~12 cm) with each mass having 150-500 eggs (Reichel & Flath 1995). The presence of egg masses and larvae identified breeding areas. Several lakes/ponds were visited on almost a daily basis and at various hours of the day that allowed for observations of local (within-lake) distributional changes. Two adults, two juveniles, and three larvae were collected and kept as voucher specimens to verify identification. Specimens were drowned in 95% ethanol, fixed in 10% formalin, and stored in containers of 95% ethanol (Maxell personal communication).

Incidental observation of macroinvertebrates presence was recorded for most sites. Zooplankton samples from lakes were also collected using a zooplankton net and preserved in formalin. Samples were collected and will be processed by Dr. Nancy Butler of Gustavus Adolphus University (in preparation).

Results

Following the first field season the baseline data set includes 1) a species presence and abundance list for each site (Appendix 1), 2) spatial distribution of individual amphibian life stages within each site and across the study area including site and area (Figure 2), and 3) a comprehensive terrestrial and aquatic habitat description (with maps) of each site (Appendix 2).

Water bodies were classified into four types as described below (Table 2).

Lake: A water body included on the USGS 7.5 minute topographical map (Fossil Lake, Montana). The lakes surveyed range in area from 0.4 to 13.1 acres. All lakes have a maximum depth greater than or equal to 1.5 m. Of the seventeen lakes surveyed, seven are fishless and ten have fish (Marcuson and Poore 1995, MTFWP data 1999). Fishless lakes range in elevation from 2790 to 2965 m while lakes with fish range from 2757 to 3011 m. Adult spotted frogs occurred in five (71%), juveniles in four (57%), and egg masses in three (43%) of seven fishless lakes. Adult spotted frogs occurred in four (40%), juveniles in two (20%), and egg masses in three (30%) of ten lakes with fish (Table 3).

Temporary Pond: A water body not included on the USGS 7.5 minute topographical map (Fossil Lake, Montana) and encountered incidentally. The ponds surveyed were less than 0.4 acres and most are much smaller (e.g., 10 m x 10 m). The maximum water depths of most ponds range from 0.2 m to 1 m. Most of these ponds either dry up by late summer or freeze to the bottom in winter. Of the nineteen ponds surveyed, sixteen are fishless and three have fish. Fishless ponds range in elevation from 2763 to 2874 m while ponds with fish range from 2790 to 2880 m. Adult spotted frogs occurred in ten (62.5%), juveniles in three (19%), and egg masses in three (19%) of sixteen fishless ponds. No spotted frogs of any life stage occurred in three ponds with fish (Table 3).

Marsh: A water body not included on the USGS 7.5 minute topographical map (Fossil Lake, Montana) and encountered incidentally. The marsh areas lack a single concentration of water and include a meandering stream and abundant emergent vegetation. Water in most of the marsh dries up by mid-August. The maximum water depth is 0.3 m. Of the two marshes surveyed, both are fishless. The marsh areas range in elevation from 2760 to 2820 m. Adult spotted frogs occur in two (100%), juveniles in two (100%), and egg masses in one (50%) of two fishless marshes (Table 3).

Table 1. The physical characteristics of various surveyed site types.

Site Type	Number Surveyed	Area Range (acres)	Depth Range (m)	Elevation Range (m)	Number with amphibian presence	Number with fish presence
Lake	17	0.4 - 13.1	> 1.5	2757 - 3011	10	10
Pond	19	< 0.4	0.2 - 1.5	2763 - 2880	10	3
Marsh	2	variable	0.3	2760 - 2820	2	0
Stream	7	variable	0.05 - 0.5	2790 - 3011	1	5 *

* Fish assumed to be present in permanent streams up and downstream from an established fish population, even when presence was not actually observed.



	<i>Rana luteiventris</i>		
	Adult	Breeding	Absent
Brook trout			
Grayling			
No fish			

Table 2. Amphibian presence in sites with and without fish. Presence of various amphibian life-stages is presented and can be compared between site types and fish presence.

	Fishless	with Fish
Lake	(N = 7)	(N = 10)
# with Adult	5 (71%)	4 (40%)
# with Juvenile	4 (57%)	2 (20%)
# with Breeding	4 (57%)	3 (30%)
No amphibian presence	2 (28.5%)	5 (50%)
Temporary pond	(N = 16)	(N = 3)
# with Adult	10 (62.5%)	0 (0%)
# with Juvenile	3 (19%)	0 (0%)
# with Breeding	5 (31%)	0 (0%)
No amphibian presence	6 (37.5%)	3 (100%)
Marsh	(N = 2)	(N = 0)
# with Adult	2 (100%)	
# with Juvenile	2 (100%)	
# with Breeding	1 (50%)	
No amphibian presence	0 (0%)	
Stream	(N = 2)	(N = 5)
# with Adult	1 (50%)	0 (0%)
# with Juvenile	1 (50%)	0 (0%)
# with Breeding	1 (50%)	0 (0%)
No amphibian presence	1 (50%)	5 (100%)

Stream: A water body with directional flow connecting lakes. Some are included on the USGS 7.5 minute topographical map (Fossil Lake, Montana). The maximum water depth ranges from 5 to 50 cm. Of seven streams surveyed, two are fishless and five potentially have fish. It was assumed that fish were present in permanent streams up and downstream from an established lake fish population. Major barriers (e.g. waterfall or >14% incline) in these connecting waters would alter this assumption. The topography and longitudinal elevation profiles of each stream are highly variable and range in elevation from 3011 to 2790 m. Adult spotted frogs occur in one (50%), juveniles in one (50%), and egg masses in one (50%) of two fishless streams. No spotted frogs of any life stage occurred in five streams presumed to have fish present (Table 3).

Quantification of fish was extremely limited but a gillnet was set in five lakes. Several fish stomach analyses were conducted of both brook trout and arctic grayling. Six brook trout were caught from Sliver Lake (48), one was 30.5 cm and five were 25 cm total length. Stomach analysis of two females showed mosquito and caddisfly larvae as the major gut contents. All captured fish were thin. To verify the absence of fish, a gillnet was set in Grover Lake (48A), no fish were caught. Sixteen brook trout were caught from Little Mocassin Lake (52A). The stomachs of two female and one male were examined. Two stomachs were empty and the third had several clam shells. Two of the trout were infected with parasites. Fish varied in total length 15 - 37 cm (average = 28 cm) and weight 0.04 - 0.5+ kg (average = 0.27 kg). Three grayling were caught from Little Washtub Lake (51), two male and one female. All grayling had full stomachs and appeared in good health. Gut contents included beetles, caddisfly larvae, and leeches. Fish ranged 28.5 - 31 cm in length and weighed an average 0.27 kg. Four brook trout were examined from Cliff Lake (50), three female and one male. Stomachs contained caddisfly larvae, leeches, and beetles. No parasites were apparent and fish were in good health. These trout ranged 18.5 - 42 cm total length and 0.09 to 0.7 + kg. In all stomachs that were examined, no evidence was seen of frog remains of any life stage.

Analysis

The primary goal of preliminary data analysis is to identify whether fish occurrence in a site is informative when predicting frog presence and abundance. Various univariate and multivariate statistical analyses were conducted on collected data.

Field observation and subsequent analysis has shown that frogs are not randomly distributed within a site. Adults and larvae have an affinity for shallow areas with emergent vegetation and gradual shoreline. Of over 400 adult and juvenile frogs counted, less than 20 were found in habitat other than shallow, vegetated areas.

Outlier analysis identified two sites as outliers, Recruitment Lake and Little Washtub Lake. Recruitment Lake exhibits the most extreme environmental data, exceeding 3000 m elevation, 53014 m², and 15 m maximum depth. Little Washtub Lake is the only site where grayling are present. Spotted frog abundance is the greatest at this site (relative abundance = 91 adults, 21 juveniles, 20 egg masses) with the greatest potential encounter rate (236). Recruitment Lake will be excluded from future data analysis. Little Washtub will be included in future analyses because important population trends may be overlooked without these data.

The data set consists of several categorical and continuous variables. Several of these are correlated. Site elevation, area, perimeter, and maximum depth are all significantly correlated (Pearson's 2-tailed, $r > 0.342$, $p < 0.05$). Other shoreline characteristics are significantly correlated to each other ($r > 0.387$, $p < 0.05$). Adult frog abundance is negatively correlated with

site elevation ($r = -0.379$, $p = 0.025$) and positively correlated with fish presence ($r = 0.427$, $p = 0.011$). This positive correlation with fish presence is unexpected and indicates that frogs are more abundant where fish are present.

Field experience and statistical analysis have shown that frogs are not randomly distributed within a site. Adults and larvae have an affinity for shallow areas with emergent vegetation and gradual shoreline ("suitable"). The proportion of suitable perimeter that is both) is significantly higher in site with frogs (ANOVA, $p = 0.014$). This perimeter suitability is a strong predictor of frog occurrence. The distance to the nearest other site with frogs and/or breeding activity is another good predictor of frog presence in a surveyed site (ANOVA, $p < 0.02$). General habitat characteristics are not significantly different between sites where frogs are present and absent except for perimeter.

Fish are typically stocked in large, deep lakes. ANOVA analysis shows a significant difference in general habitat characteristics between sites with and without fish. The number of site inlets or outlets is also a significant predictor of fish presence (ANOVA, $p < 0.05$).

Frog abundances cannot be compared directly between sites due to variable surveyed area. To obtain a metric that accounts for these site variations an encounter rate was calculated. It did not seem adequate to determine abundance/area since spotted frogs (especially adults) do not utilize the entire wetted surface. Frogs and tadpoles have an obvious affinity for shallow shoreline but perimeter measurements were not taken. However, time spent surveying the entire site can approximate perimeter. Suitable perimeter is estimated indirectly with the time spent surveying these areas. The resulting encounter rate is corrected for site perimeter and habitat availability and is a measure of the number of frogs encountered per hour within suitable shoreline. Subsequent comparison of raw abundance counts to encounter rate did not result in any new information. It is concluded that raw scores are adequate and are used in the following analyses. Adult frog presence and abundances are not significantly different in fish and fishless sites. Two sites (Cliff Lake, Little Moccasin) were excluded from a later analysis that could potentially conceal a relationship between fish presence and frog abundance/presence. No significant differences were found (ANOVA, $p_{\text{presence}} = 0.304$, $p_{\text{abundance}} = 0.106$).

A backward multiple regression was performed to identify the variables most predictive of adult frog presence and abundance at $\alpha = 0.05$. Both models identify area and fish presence as significant parameters. Site elevation and distance to the nearest frog site are also significant to the frog presence model. Fish type, abrupt perimeter, and the number of inlets are significant in the abundance model.

The preceding analyses were conducted on all variables suspected to explain the occurrence and abundance of frogs and fish. Though some of these variables are independent, most are correlated. Principal components analysis (PCA) and linear discriminant analysis were performed to reduce the number of variables and to identify the most valuable parameters in the data set.

The PCA approach analyzes continuous variables to determine those that account for most of the variance in the data. Because the first two extracted components cumulatively explain only 55% of the variance, the first four principal components were examined (cumulative 75%) to determine the relationship among the variables. PC1 loads most heavily on maximum site depth, abrupt perimeter, and gradual perimeter. PC2 loads most heavily on individual abundance (adult, juvenile, and egg mass). PCA is probably not a useful tool to analyze this data set because so many components are required to explain most of the variance (> 10).

Linear discriminant function analysis was conducted based on fish presence and also for frog presence. This analysis excluded four cases that had missing data (3, 25, 31, and 38). Frog presence is most predicted by the amount of suitable habitat, distance to the nearest breeding site and distance to the nearest frog site. These parameters are the most highly correlated with the structure matrix canonical variable scores and are the most useful in the discriminant function. The cross-validated classification results are more robust. 85.3% of cross-validated grouped cases were correctly classified. Fish presence is most predicted by the number of inlets to a site, area, and maximum depth. This analysis excluded the same four cases. 70.6% of cross-validated cases were correctly classified. These results are not as meaningful because of the frequency of misclassification.

Although each model discussed previously is imperfect, it is apparent that unique variables are predictive of fish or frog presence. It appears that frog occurrence is most explained by biologic interactions and habitat suitability, while fish presence is explained by physical site characteristics. This is understandable in light of the preponderance of fish stocking into lower elevation, large, and deep lakes. It is expected that these lakes can typically support a self-sustaining fishery and are accessible to recreational users.

No analysis performed to this point has identified fish as a significant predictor of frog presence. Fish presence may be an indicator of frog abundance, though an opposite relationship to that expected. Future fieldwork will need to concentrate on collecting more precise measurements of fish and frog abundance. This will allow us to identify whether fish presence excludes, increases or does not influence frog presence/abundance.

Conclusions

Spotted frog abundance data from this first field season is limited and is only a relative representation of the entire population that may occur in each water body. Typically the visual encounter survey (VES) method includes only 30% of the actual population (Peterson personal communication). Presuming that field surveys are consistent, a healthy population of Columbia spotted frogs exists in this region (approaching 1000 individuals?)

Contrary to expectations, frog and fish cooccur in these sites (Bradford et al. 1993, Bradford 1989). Not only are adult frogs and fish found together, but these waters are also used as breeding and rearing sites. Though evidence of breeding is most common and abundant in shallow, ephemeral ponds, several permanent lakes with fish were used. Frogs and tadpoles were also found in microhabitats that did not seem to provide much shelter (in and between large boulders and talus) though shallows were preferred. Preliminary analysis suggests that coexistence of frogs and fish is facilitated by shoreline complexity. Frogs are absent from several fishless sites without obvious reasons. Environmental data from these ponds/lakes may further identify preferred conditions, although elevation (>2910 m) likely explains the absence of amphibians in these sites. The preliminary data do not provide sufficient evidence to test the hypothesis that the presence/absence of trout does not affect the presence/absence of Columbia spotted frogs in this study area. However, analysis on existing data would suggest a minimal fish effect when compared to similar studies.

It has been documented that fish preferentially feed on large zooplankton (Brooks and Dodson 1965, Vanni 1988, McNaught et al. 1999). This exploitation of the large zooplankton supply may compromise overall amphibian fitness. Identification and quantification of zooplankton samples by Nancy Butler will yield important insight on this possible indirect effect

of fish presence. The presence of fish may alternatively act to control invertebrate populations decreasing predation pressure by aquatic insects.

Preliminary observation has shown a tadpole affinity for higher water temperatures. Development, growth and successful recruitment are very much determined by abiotic conditions such as water temperature (Duellman and Trueb 1986, Holomuzki 1986). In several fishless ponds/lakes, a diurnal migration of tadpoles matches major temperature fluctuations. This option to follow the thermal maximum may accelerate development and metamorphosis and increase survival to the adult stage (Heath 1975, Bizer 1978, Crump 1981, Holomuzki 1986).

By examining environmental factors that have been shown to affect larval success, it is hoped that mechanisms may be determined that identify conditions that provide for the persistence of Columbia spotted frogs. Results from this preliminary study along with future research effort will yield extremely useful information and can benefit management approaches by 1) identifying areas integral to population persistence and subsequent conservation of these areas, and/or 2) identifying abiotic and biotic site characteristics that allow for successful co-existence. Revised management may be suggested if significant negative impacts from fish presence are discovered.

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Appendix 1. Presence and abundance data for each site. *Rana luteiventris* life-history stage abundances are listed individually. Larval presence is indicated as (L). Fish data are presence only, no quantification of abundance or stage-structure was attempted.

Site	Adults	Juveniles	Egg Masses	* Fish Presence	Site	Adults	Juveniles	Egg Masses	* Fish Presence
46A	0	0	0	0	51A	0	0	0	0
46	0	0	0	0	51B	11	5	6 (L)	0
47V	0	0	0	0	51C	19	5	0	0
47W	1	0	0	0	52B	5	0	0	0
47Y	0	0	0	0	52C	2	0	0 (L)	0
48A	20	7	10	0	52D	0	0	0	0
48D	5	1	0 (L)	0	45	0	0	0	1
48W	1	6	0	0	47T	0	0	0	1
48Y	16	20	16 (L)	0	47Z	0	0	0	1
48Z	1	0	0	0	47	1	0	0	1
49A	12	20	12 (L)	0	48B	0	0	0	1
49S	5	2	3 (L)	0	48C	0	0	0	1
49Y	2	0	0	0	48	5	0	0	1
49Z	4	0	0	0	48V	0	0	0	1
49	23	1	26 (L)	0	50	44	9	1 (L)	1
50W	2	0	1 (L)	0	52A	5	21	2 (L)	1
50X	5	0	0 (L)	0	52	4	0	0	1
50Y	0	0	0	0	55A	0	0	0	1
50Z	0	0	0	0	51	91	21	20 (L)	2

* 0 = none, 1 = Brook trout (*Salvelinus fontinalis*), and 2 = Arctic grayling (*Thymallus arcticus*)

Appendix 2: Physical characteristics of surveyed sites. Site number and names follow Marcuson (1985) with several ephemeral sites being numbered and named by the investigator. * 1 = lake, 2 = pond, 3 = marsh, and 4 = stream.

Site #	Site Name	* Site Type	Elevn (m)	Area (m ²)	Depth (m)	Site #	Site Name	* Site Type	Elevn (m)	Area (m ²)	Depth (m)
46A	Wyrick	2	3013	2428	3.4	51A		2	2810	40	0.5
46	Pneumonia	1	3011	14569	10.1	51B		2	2807	401	0.5
47V		2	2862		0.15	51C		3	2804	3751	0.3
47W		2	2908	61	0.3	52B		2	2914	1619	0.9
47Y		2	2914	227	1.2	52C		2	2914	749	0.8
48A	Grover	1	2890	5261	4.6	52D		2	2868		0.6
48D		2	2835	2428	3.1	45	Recruitment	1	3060	53014	16.2
48W		2	2920	219	0.6	47T		2	2914	1251	1.2
48Y		2	2920	676	0.6	47Z		2	2926	73	1.2
48Z		2	2914	449	0.3	47	Hunger	1	2946	20639	9.5
49A	Kermit	1	2908	1619	0.9	48B		2	2835	2428	1.5
49S		3	2865	35	0.3	48C		2	2835	1619	2.7
49Y		2	2871	198	0.3	48V		2	2790		0.6
49Z		2	2871	178	0.9	48	Sliver	1	2902	27923	6.7
49	Peanut	1	2900	8094	6.4	50	Cliff	1	2816	26709	6.1
50W		2	2865	599	0.6	52A	Little Mocassin	1	2867	3238	3.4
50X		2	2819	239	0.6	52	Mocassin	1	2865	27519	9.1
50Y		2	2865	441	0.5	55A		1	3025	2833	1.5
50Z		2	2865	40	0.5	51	Little Washtub	1	2801	8903	9.1